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# Soil physical data:
## documentation of a computer file

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# Soil physical data:
## documentation of a computer file

R. DEJONG and K. LOEBEL
Land Resource Research Institute
Ottawa, Ontario

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## SUMMARY

The soil physical data file is a computerized information file which has been established in order to capture data which cannot be entered into one of the CanSIS files. Basically conceived as a tool to aid scientists in soil water modeling, the file enables the storage, retrieval and manipulation of soil physical data.

The organization of the data file is described. While the file contains those soil physical data which are important with regard to soil water modeling, the sequential format of the file allows for easy expansion such that chemical and biological data could be included. Examples of how the file has been, and can be, used for developing and testing input functions for soil water models are given.

## RÉSUMÉ

Le fichier de données physiques sur les sols est un fichier informatisé qui a été mis au point de manière à pouvoir saisir des données qui ne peuvent autrement être introduites dans un des fichiers du système SISCan. Conçu tout d'abord en tant qu'outil de travail pour les scientifiques oeuvrant dans le domaine de la modélisation du régime hydrique des sols, le fichier permet également le stockage, l'extraction et la manipulation de données physiques sur les sols.

On trouvera dans le présent document la description de l'organisation du fichier de données. Le fichier renferme actuellement les données physiques sur les sols qui revêtent de l'importance dans le domaine de la modélisation du régime hydrique du sol mais sa présentation, sur le mode séquentiel, permet d'y introduire facilement des données chimiques et biologiques. Le document présente également des exemples d'utilisations réelles et éventuelles du fichier pour la mise au point et la vérification de fonctions de saisie concernant les modèles de régimes hydriques des sols.

CONTENTS


| | | PAGE |
|---|---|---|
| INTRODUCTION | | 1 |
| ORGANIZATION OF THE DATA FILE | | 2 |
| UTILIZATION OF THE DATA FILE | | 3 |
| I. | Developing relationships among variables present in the file | 3 |
| II. | Testing relationships from different data sets | 4 |
| III. | Direct input to soil water models | 5 |
| REFERENCES | | 10 |
| Appendix A. | Record Identification | 12 |
| Appendix B. | List of Investigators | 15 |
| Appendix C. | Codes Assigned to Taxonomic Classification | 17 |
| Appendix D. | Codes Assigned to Soil Textural Classes | 22 |

## INTRODUCTION

The science of soil physics, being the study of the state and transport of matter and energy in the soil (Hillel, 1971), has a large and diverse data requirement because the soil itself is of utmost complexity. The soil matrix consists of numerous irregularly fragmented components which are arranged in an intricate geometric pattern. Some of the solid material consists of crystalline particles, while some consists of amorphous material which attaches itself to the crystalline particles and bonds them together. This solid phase interacts with the fluids and gases which permeate the soil pores. This interaction which is referred to as the soil-water complex is rarely in a state of equilibrium, as it alternately wets and dries, swells and shrinks, cracks, aggregates, compacts, and undergoes chemical changes and structural rearrangements. Since the soil exhibits at all times these exceedingly complex interactions among its constituents, it is almost impossible to define completely its exact physical state at any one time. In dealing with any particular soil and condition, therefore, soil water modeling and simulation techniques have been developed for the purpose of providing a comprehensive quantitative description of the dynamic behaviour of the soil-water complex.

The soil physical data which are required to operate the models vary in quantity and complexity (De Jong, 1981). For example, soil water characteristic data are required to describe the availability of soil water to plants and to model the movement of water and solutes in unsaturated soils. They also constitute input data for hydraulic conductivity models and are essential for calculating soil water diffusivity from water content data. However, since obtaining these data is time consuming and expensive, it is often necessary to predict the required information from other soil physical data like particle size distributions and organic matter content data. Similarly, bulk density and saturated hydraulic conductivities are frequently missing from data sets and have to be estimated from more easily measured parameters (Bloemen, 1980; Rawls, 1983).

A limited amount of soil physical data can be stored in the Canada Soil Information System (CanSIS), described by MacDonald and Kloosterman (1984). Unfortunately, however, the CanSIS data base does not allow for the storage and management of the detailed soil physical data which are required input for soil water modeling analyses. For example soil water characteristic and hydraulic conductivity curves cannot be entered into the system. Measurements of field capacity, permanent wilting point and soil thermal properties are not defined. In addition, CanSIS is not well suited to handle analytical data from samples for which there is no accompanying field description (such as profile

description, sampling location, etc.). This leaves valuable information sources, such as scientific manuscripts, theses and unpublished reports, untapped in terms of data utilization.

Because of the need for many, and often difficult to measure, soil physical data to (i) develop and test input functions for soil water models and (ii) execute and apply soil water models to local or regional problems, it is essential to take advantage of all potential data sources. Therefore, in order to capture data not entered into CanSIS, a soil physical data file was developed. This technical bulletin describes the file and its contents; it also gives examples of how the file has been used. Further information or access to the file can be obtained by contacting the aut' rs of this bulletin.

## ORGANIZATION OF THE DATA FILE

The soil physical data file is resident on DATACROWN and the Agriculture Canada Network (AGNET). To retrieve and/or copy data from the file directly or indirectly (by means of a tape or a card deck) the users must contact the authors of this bulletin. The structure of the file can be compared to a simple two dimensional matrix, where fields (also called variables) form the vertical columns, and data records (groups of observations) form the horizontal rows. In this data file all data records can be identified by the investigator who collected the data (see Appendix B); moreover all data records are numbered consecutively.

## VARIABLES

| INVESTI-GATOR | SOIL ORDER | GREAT GROUP | SUB GROUP | SERIES NAME | TEXTURAL CLASS | HORIZON |
|---|---|---|---|---|---|---|
| 13 | 1 | 2 | 02 | PINERIDGE | 3 | A |
| 13 | 5 | 2 | 02 | MORTON | 4 | A |
| 13 | 2 | 3 | 06 | PLUMRIDGE | 3 | A |
| 13 | 2 | 3 | 07 | REDRIVER | 13 | A |
| 13 | 2 | 3 | 01 | WELLWOOD | 4 | A |
| 13 | 2 | 3 | 01 | WELLWOOD | 8 | B |
| 13 | 2 | 3 | 01 | WELLWOOD | 11 | C |
| 14 | 5 | 1 | 02 | FOX | 3 | A |
| 14 | 5 | 1 | 02 | FOX | 2 | A |
| 14 | 5 | 1 | 02 | FOX | 1 | A |

Appendix A outlines the field descriptions and the units of each variable. The values in coded fields consist of a limited number of defined codes. The coded variables 'investigator', 'taxonomic classification' and 'soil textural class' are described in Appendices B, C and D, respectively.

While most variables outlined in the format statement of Appendix A deal with or are related to soil water properties, the file could readily be expanded to include other soil physical data as well as chemical and biological data. For example, if there was a need for thermal properties the data reported by Edey and Joynt (1975) could be added to the file. However, very few, if any, records would contain a complete set of physical, chemical and biological data.

At present 1026 records have been entered into the data file. All the soil Orders, except the Organic and Cryosolic Order, are represented in the file. There are no data in the file from the following provinces: Newfoundland, New Brunswick and Prince Edward Island. The file will be updated periodically when more data become available.

## UTILIZATION OF THE DATA FILE

I. Developing relationships among variables present in the file

(a) Due to the difficulties involved in measuring soil water retention curves many attempts have been made to obtain this information from more readily available soil properties. De Jong et al. (1983) examined relationships between soil water content and water suction, relating water retention equations to textural and organic carbon content data. The data used in that study came from investigator number 17 (Appendix B), and consisted of disturbed samples of 18 soils representing various soil Great Groups of the Canadian prairies.
An empirical two-straight-line model was found to be most suitable to relate soil water content to water suction. Texture was shown to be the main soil property influencing the shape and position of the water retention curve. Organic matter increased the water content at which a break in the curve occurred, but had little effect on the rate of release of water or the soil suction at which water became more difficultly desorbed.

(b) In an attempt to approximate the soil water desorption curve, modeled as a power curve, from limited data, De Jong (1983) selected undisturbed soil water retention data, which consisted of at least eight measured water contents at various tensions. Consequently the model was tested on 90 soil samples, with the data coming from investigators number 2, 9, 10, 11, 12, 15, 16 and 18 (Appendix B). The results indicated that measurements at the two extremes were most important, if only two water contents were measured. The best results were obtained when the curve was fitted through three

measured water contents, respectively at saturation, at an intermediate tension and at a high tension (see Fig. 1).

(c) The data in the file have also been used to develop a relationship between total porosity and soil bulk density. One hundred and twenty three records which contained total porosity and bulk density measurements were selected. A simple linear regression program was used to develop the relation:

$$P_{tot} = (2.52 - BD)/2.36 \qquad r = 0.94$$

where porosity, $P_{tot}$, was expressed in $cm^3cm^{-3}$, and bulk density, BD, was expressed in g $cm^{-3}$. This equation agrees to within $\pm$5% with the commonly accepted relationship:

$$P_{tot} = (2.65 - BD)/2.65$$

as is shown below:

| BULK DENSITY ($g/cm^3$) | PREDICTED POROSITY ($cm^3cm^{-3}$) | |
|---|---|---|
| | $P_{tot}=(2.52 - BD)/2.36$ | $P_{tot}=(2.65 - BD)/2.65$ |
| 0.8 | 0.73 | 0.70 |
| 0.9 | 0.69 | 0.66 |
| 1.0 | 0.62 | 0.64 |
| 1.1 | 0.59 | 0.60 |
| 1.2 | 0.55 | 0.56 |
| 1.3 | 0.51 | 0.52 |
| 1.4 | 0.47 | 0.48 |
| 1.5 | 0.43 | 0.43 |

II. Testing relationships from different data sets

(a) De Jong and Loebel (1982) utilized information available in the CanSIS Detail 2 file for soil-water modeling purposes by developing regression equations which related physical and chemical soil components to water retention. Particle size distribution and organic carbon content data were related to soil water contents at 1/3 and 15 atmosphere tension, determined on disturbed samples, for various soil Orders in Canada. The developed regression equations were tested against the independent data in the soil physical data file. The agreement between the predicted and the measured data was generally good.

(b) Clapp and Hornberger (1978) have presented standardized empirical soil water characteristics for 11 textural groups. These equations were derived from desorption data reported by Holtan et al. (1968), whose data set consisted of 176 sampled soil types from 34 locations in the United States. De Jong (1982) investigated the applicability of the parametric equations using Canadian data from the soil physical data file (investigators number 2, 9, 10, 11, 13, 14, 16 and 18 were employed). Regression analysis showed a satisfactory agreement between measured water contents and those predicted by the Clapp and Hornberger equations. An example for the loam textural group is shown in Figure 2. For specific individual soils the prediction equations were found to be less applicable, and dependent upon the selected variability criteria.

(c) According to Ayres et al. (1973), the saturated hydraulic conductivity is a function of the percentage of large soil pores, which may be estimated from the fraction of the soil occupied by air at 1/3 atmosphere suction. Using data from Chernozemic and Solonetzic soils, hydraulic conductivity (K, cm $hr^{-1}$) and air filled porosity at 1/3 - atm suction (S, $cm^3$ $cm^{-3}$) were related by the relationship:

$$K = -1.8 + 23\ S$$

which is plotted in Figure 3. Data from the Ottawa area, investigators number 9 and 10 are also plotted in figure 3. It appears that there is an order of magnitude difference between the displayed functional relationship and the data from the Ottawa area. Although one might speculate on the causes for this discrepancy, it is here sufficient to remark that the measured data in the file were used to test a relationship, developed from a different data set.

III. Direct input to soil water models

(a) Hydraulic conductivity functions can be derived from measured soil water characteristic curves in the soil physical data file. To do this, on a physically consistent basis, one can use the theory first developed by Childs and Collis-George (1950), later modified by Marshall (1958) and Millington and Quirk (1961) and recently reformulated by Kunze et al. (1968) and Jackson (1972). In principle, this theory makes it possible to calculate the entire conductivity-wetness function, including the hydraulic conductivity at saturation. In

practice, however, it has been found to yield more realistic estimates when pegged to experimentally determined values of hydraulic conductivity at saturation. The latter data can be found in the soil physical data file.

(b) The soil water characteristic curves and the saturated hydraulic conductivity measurements, present in the soil physical data file, can be used as input to physical based soil water simulation models. One such model is that described by Hayhoe and De Jong (1982) who used standardized Clapp and Hornberger (1982) type functions for soil water transfer properties. Another of the physical based models, MUST, developed by De Laat (1980), simulates transient unsaturated flow above a shallow water table. Transient flow is solved by a sequence of steady state situations, subject to boundary flux conditions. Functions relating hydraulic conductivity to suction head are required inputs for the model.

(c) The Versatile Soil Moisture Budget, developed by Baier et al. (1979) requires soil water holding capacity data as input. This information can be obtained directly from the soil physical data file, since it stores field capacity and permanent wilting point data. It is also possible to calculate the information from particle size distribution and organic carbon content data in the file.

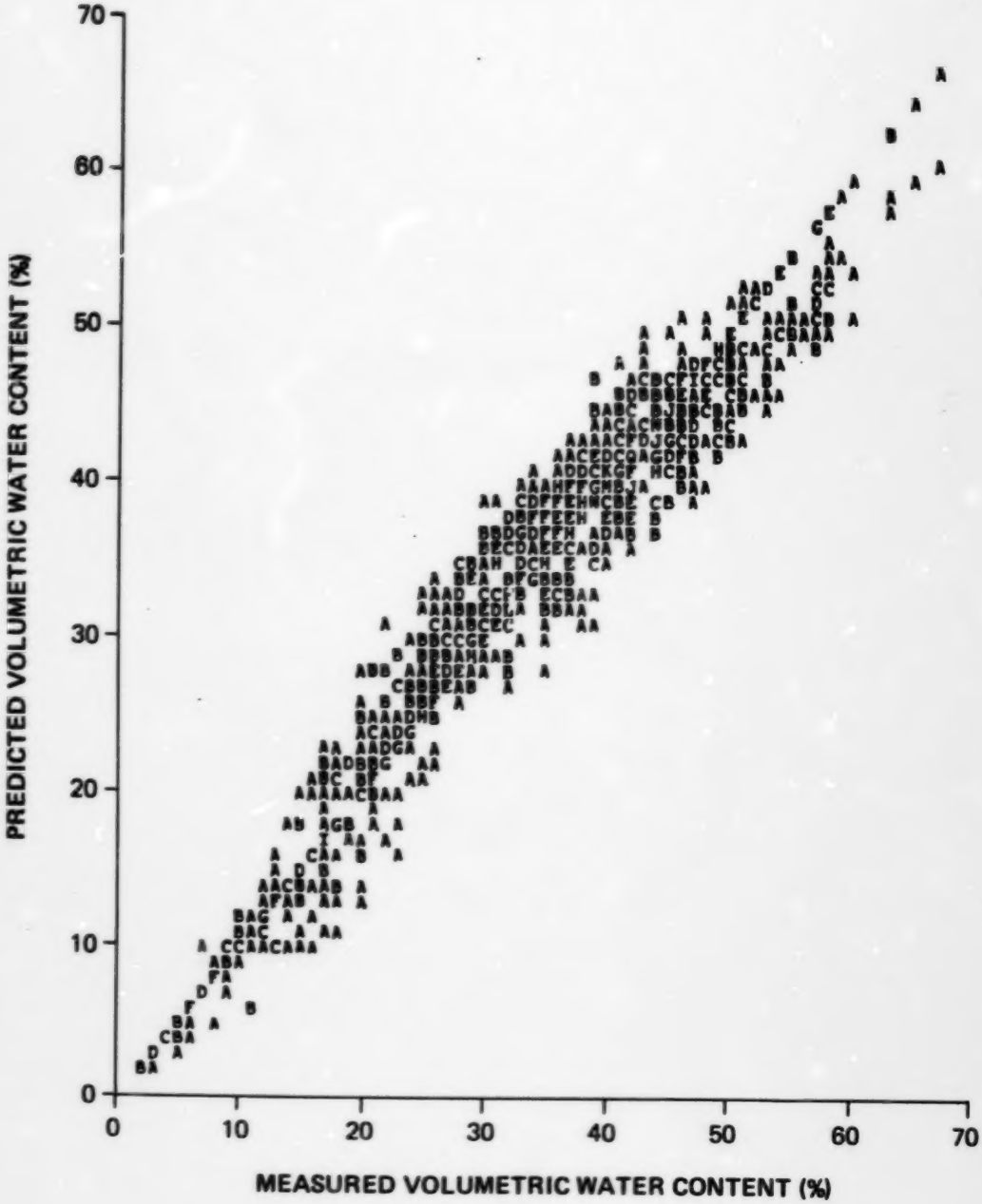


Figure 1. The measured and predicted water contents of samples when the soil water desorption curve was fitted through three measured water contents at 0.0, 5.0 or 6.0 and 1500.0 kPa tension. A = 1 observation; B = 2 observations; etc. (from the soil physical data file).

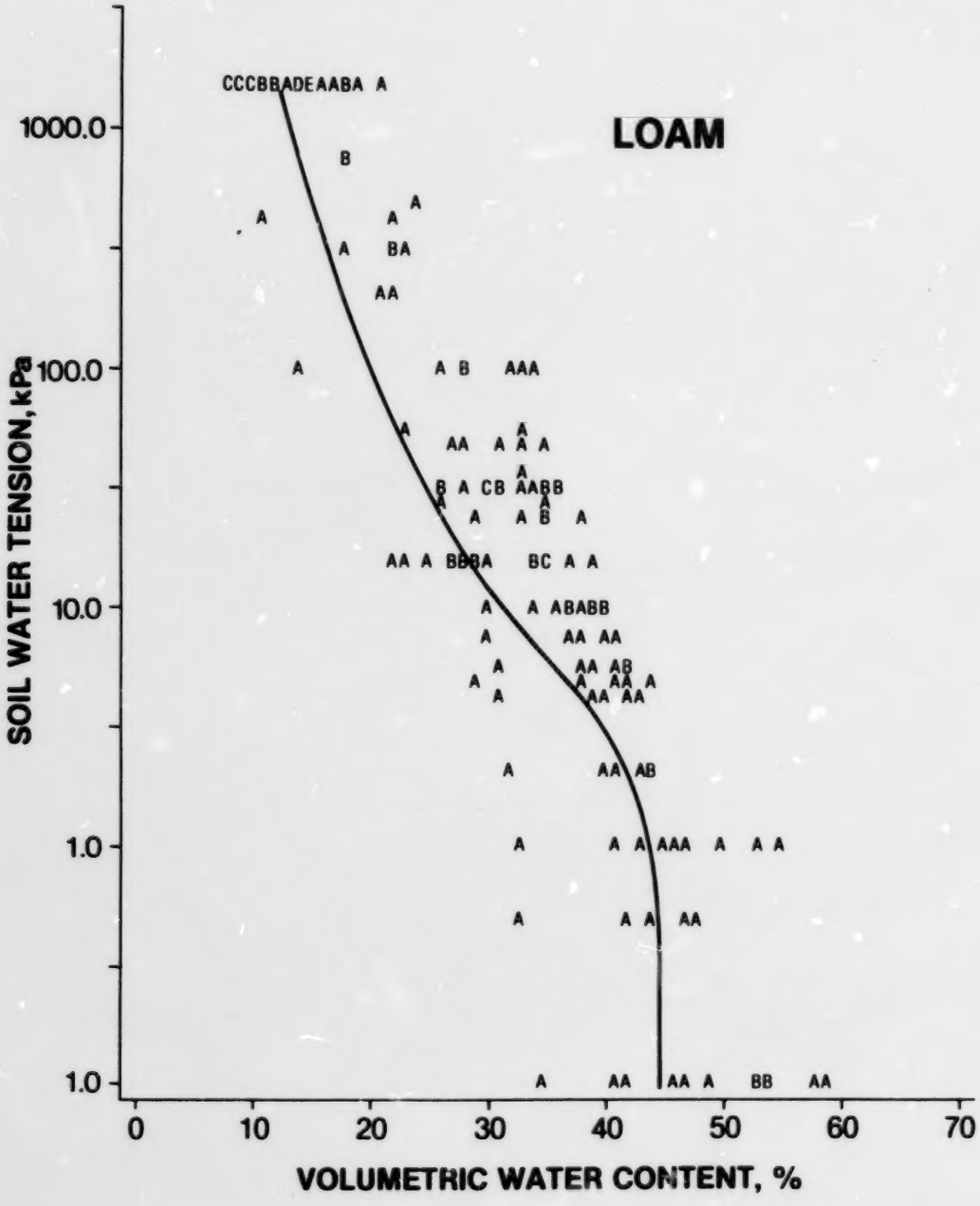


Figure 2. Soil water characteristic for the loam textural class predicted by Clapp and Hornberger (1978). A = 1 observation; B = 2 observations, etc. (from the soil physical data file).

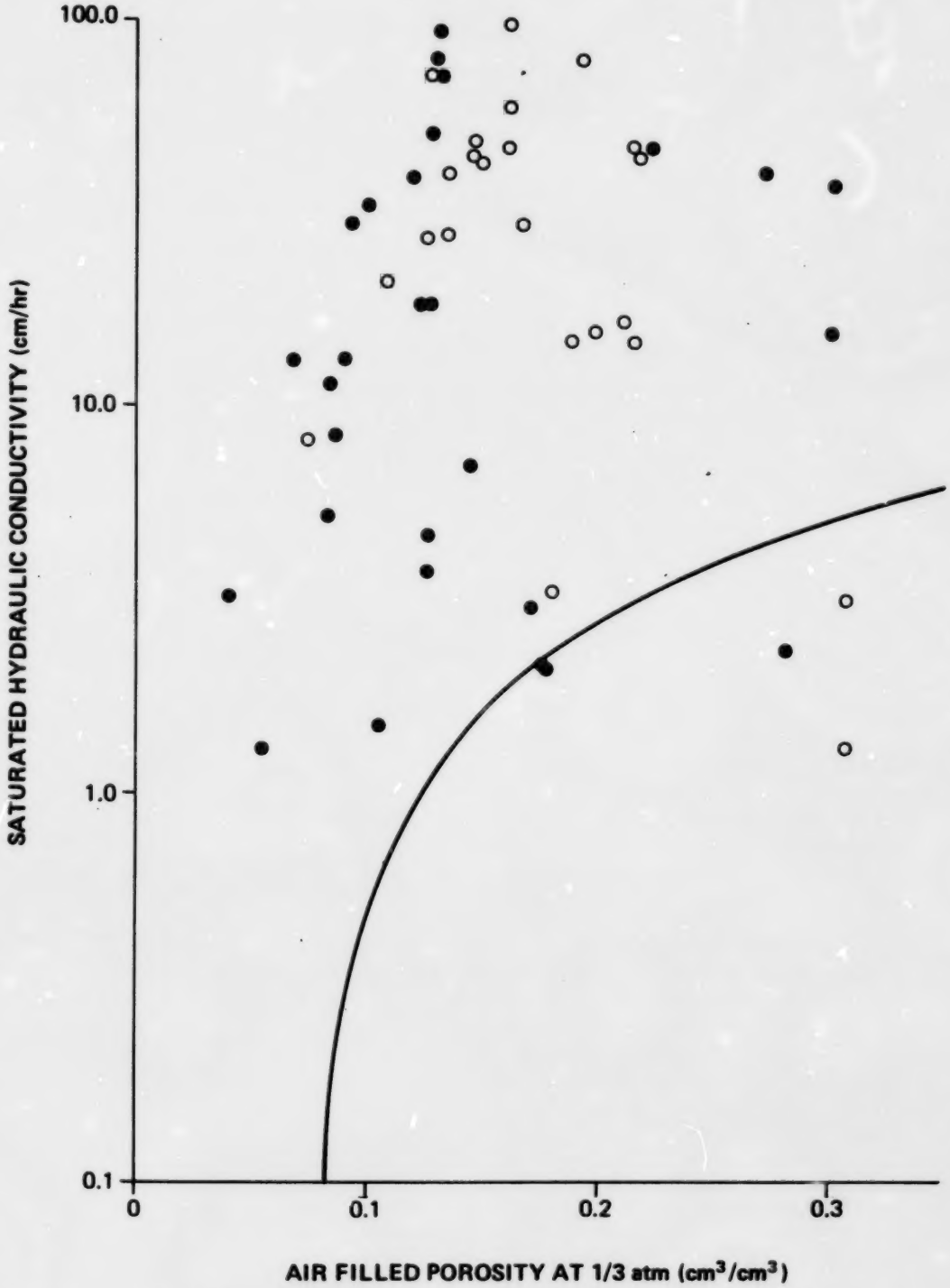


Figure 3. The relationship between saturated hydraulic conductivity and air filled porosity at 1/3 atmosphere. predicted by Ayres et al. (1973).
● = data from investigator number 9.
o = data from investigator number 16.

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Marshall, T.J. 1958. A relation between permeability and size distribution of pores. J. Soil Sci. 9:1-8.

Millington, R.J. and J.P. Quirk. 1961. Permeability of porous solids. Trans Faraday Soc. 57:1200-1206

Rawls, W.J. 1983. Estimating soil bulk density from particle size analysis and organic matter content. Soil Sci. 135:123-125.

## APPENDIX A

### RECORD IDENTIFICATION

| COLUMN | FIELD DESCRIPTION |
|---|---|
| 1-2 | Name of investigator (coded, see Appendix B) |
| 3 | Soil Order (coded, see Appendix C) |
| 4 | Great Group (coded, see Appendix C) |
| 5-6 | Subgroup (coded, see Appendix C) |
| 7-16 | Series or association name, according to investigator (abbreviated when longer than 10 characters) |
| 17-18 | Textural class (coded, see Appendix D) |
| 19 | Master horizon |
| 20 | Units of sampling depth (coded)<br>1 = cm<br>2 = inch |
| 21-23 | Start of sampling depth (If units are in cm there is no implied decimal, if |
| 24-26 | End of sampling depth units are in inches, the decimal is implied before the last digit.) |
| 27-30 | Sand, % (decimal implied before the last two digits) |
| 31-34 | Silt, % (decimal implied before the last two digits) |
| 35-38 | Clay, % (decimal implied before the last two digits) |
| 39 | Identification of % organic material (coded)<br>1 = % organic matter<br>2 = % organic carbon |
| 40-43 | Organic material, % (decimal implied before last two digits) |
| 44 | Method for determining bulk density (coded)<br>1 = core method<br>2 = clod method<br>3 = other |
| 45-47 | Bulk density, g $cm^{-3}$ (decimal implied before last two digits) |
| 48 | Identification of next variable (coded)<br>1 = porosity, % by volume<br>2 = particle density, g $cm^{-3}$ |
| 49-52 | Porosity or particle density (decimal implied before last two digits) |
| 53 | Units of water content (coded)<br>1 = % water on a gravimetric basis<br>2 = % water on a volumetric basis |
| 54-57 | Field capacity, measured in the field, % water by weight (decimal implied before last two digits) |
| 58-61 | Permanent wilting point, sunflower method, % water by weight (decimal implied before last two digits) |

| COLUMN | FIELD DESCRIPTION |
|---|---|
| 62-66 | Saturated hydraulic conductivity, cm $hr^{-1}$ (decimal implied before the last two digits) |
| 67-71 | Steady infiltration rate, cm $hr^{-1}$ (decimal implied before last two digits) |
| 72 | Units of water retention curve (coded)<br>1 = cm water<br>2 = atmosphere<br>3 = bar |
| 73 | Method for determining saturated hydraulic conductivity (coded)<br>0 = disturbed soils (or not determined)<br>1 = core method<br>2 = in situ method |
| 74 | Cultivation history (coded)<br>1 = virgin soil<br>2 = stubble soil |
| 75 | Method for measuring water retention curve (coded)<br>0 = disturbed soil (or not measured)<br>1 = undisturbed core |
| 76-79 | Record number |
| 80 | Identification whether or not water retention curve was measured (coded)<br>0 = not measured<br>1 = data follows |
| 81-89 | Water retentiCn information. First four positions (81-84) give the water content (decimal implied before last two digits, units determined in column 53). Last five positions (85-89) give the tension or pressure head (if the units are in cm water, then there is no implied decimal, if the units are in atmospheres or bars, the decimal is implied before the last three digits). |
| 90-98 | Same as column 81-89, but at different tension |
| 99-107 | Same as column 81-89, but at different tension |
| 108-116 | Same as column 81-89, but at different tension |
| 117-125 | Same as column 81-89, but at different tension |
| 126-134 | Same as column 81-89, but at different tension |
| 135-143 | Same as column 81-89, but at different tension |
| 144-152 | Same as column 81-89, but at different tension |
| 153-156 | Blank |
| 157-159 | Record number |
| 160 | Identification whether or not more water retention data were measured (coded)<br>0 = no more measured data<br>2 = more measured data follow |
| 161-169 | Same as column 81-89, but at different tension |
| 170-178 | Same as column 81-89, but at different tension |
| 179-187 | Same as column 81-89, but at different tension |

| COLUMN | FIELD DESCRIPTION |
|---|---|
| 188-196 | Same as column 81-89, but at different tension |
| 197-205 | Same as column 81-89, but at different tension |
| 206-214 | Same as column 81-89, but at different tension |
| 215-236 | Blank |
| 237-239 | Record number |
| 240 | Blank |

Additional columns could be used for other properties.

## APPENDIX B

## LIST OF INVESTIGATORS

| CODE | INVESTIGATOR |
|---|---|
| 1 | SHAYKEWICH, C.F. 1965. The relationship between soil components and soil physical constants of some Manitoba soils. Unpublished M.Sc. Thesis, Univ. of Man., Winnipeg, Man. |
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| 11 | DE KIMPE, C.R., MCKEAGUE, J.A. and TOPP, G.C. 1974. Soil properties in relation to water regime at a site near Quebec city. Can. J. Soil Sci. 54:427-446. |
| 12 | CAMERON, D.R. 1979. Variability of soil water retention curves and predicted hydraulic conductivities on a small plot. Soil Sci. 126:364-371. |

| CODE | INVESTIGATOR |
|---|---|
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| 15 | WEBSTER, D.H. and TOPP, G.C. 1983. Measurement of capillary rise under field conditions and related soil properties. Kentville Res. Stn. Tech. Bull. No. 3, Res. Branch, Agric. Canada. |
| 16 | TOPP, G.C. 1979. Soil water structure group, 1979 data. Unpublished data, L.R.R.I. |
| 17 | DE JONG, R., CAMPBELL, C.A. and NICHOLAICHUK, W. 1983. Water retention equations and their relationship to soil organic matter and particle size distribution for disturbed samples. Can. J. Soil Sci. 63:291-302. |
| 18 | DE JONG, R. and BAILEY, W.G. 1981. Unpublished data from the Beaverlodge, Alberta area. |

## APPENDIX C

### CODES ASSIGNED TO TAXONOMIC CLASSIFICATION

| CODE | ORDER | CODE | GREAT GROUP | CODE | SUBGROUP |
|---|---|---|---|---|---|
| 1 | Brunisolic | 1 | Melanic Brunisol | 1 | Orthic Melanic Brunisol |
| | | | | 2 | Eluviated Melanic Brunisol |
| | | | | 3 | Gleyed Melanic Brunisol |
| | | | | 4 | Gleyed Eluviated Melanic Brunisol |
| | | 2 | Eutric Brunisol | 1 | Orthic Eutric Brunisol |
| | | | | 2 | Eluviated Eutric Brunisol |
| | | | | 3 | Gleyed Eutric Brunisol |
| | | | | 4 | Gleyed Eluviated Eutric Brunisol |
| | | 3 | Sombric Brunisol | 1 | Orthic Sombric Brunisol |
| | | | | 2 | Eluviated Sombric Brunisol |
| | | | | 3 | Duric Sombric Brunisol |
| | | | | 4 | Gleyed Sombric Brunisol |
| | | | | 5 | Gleyed Eluviated Sombric Brunisol |
| 2 | Chernozemic | 1 | Brown | 1 | Orthic Brown |
| | | | | 2 | Rego Brown |
| | | | | 3 | Calcareous Brown |
| | | | | 4 | Eluviated Brown |
| | | | | 5 | Solonetzic Brown |
| | | | | 6 | Gleyed Brown |
| | | | | 7 | Gleyed Rego Brown |
| | | | | 8 | Gleyed Calcareous Brown |
| | | | | 9 | Gleyed Eluviated Brown |
| | | | | 10 | Gleyed Solonetzic Brown |
| | | 2 | Dark Brown | 1 | Orthic Dark Brown |
| | | | | 2 | Rego Dark Brown |
| | | | | 3 | Calcareous Dark Brown |
| | | | | 4 | Eluviated Dark Brown |
| | | | | 5 | Solonetzic Dark Brown |
| | | | | 6 | Gleyed Dark Brown |
| | | | | 7 | Gleyed Rego Dark Brown |
| | | | | 8 | Gleyed Calcereous Dark Brown |
| | | | | 9 | Gleyed Eluviated Dark Brown |
| | | | | 10 | Gleyed Solonetzic Dark Brown |
| | | 3 | Black | 1 | Orthic Black |
| | | | | 2 | Orthic Black |
| | | | | 3 | Calcareous Black |
| | | | | 4 | Eluviated Black |
| | | | | 5 | Solonetzic Black |
| | | | | 6 | Gleyed Black |

| CODE | ORDER | CODE | GREAT GROUP | CODE | SUBGROUP |
|---|---|---|---|---|---|
| | | | | 7 | Gleyed Rego Black |
| | | | | 8 | Gleyed Calcareous Black |
| | | | | 9 | Gleyed Eluviated Black |
| | | | | 10 | Gleyed Solonetzic Black |
| | | 4 | Dark Gray | 1 | Orthic Dark Gray |
| | | | | 2 | Rego Dark Gray |
| | | | | 3 | Calcareous Dark Gray |
| | | | | 4 | Solonetzic Dark Gray |
| | | | | 5 | Gleyed Dark Gray |
| | | | | 6 | Gleyed Rego Dark Gray |
| | | | | 7 | Gleyed Calcareous Dark Gray |
| | | | | 8 | Gleyed Solonetzic Dark Gray |
| 3 | Cryosolic | 1 | Turbic Cryosol | 1 | Orthic Turbic Cryosol |
| | | | | 2 | Brunisolic Turbic Cryosol |
| | | | | 3 | Regosolic Turbic Cryosol |
| | | | | 4 | Gleysolic Turbic Cryosol |
| | | 2 | Static Cryosol | 1 | Orthic Static Cryosol |
| | | | | 2 | Brunisolic Static Cryosol |
| | | | | 3 | Regosolic Static Cryosol |
| | | | | 4 | Gleysolic Static Cryosol |
| | | 3 | Organic Cryosol | 1 | Fibric Organic Cryosol |
| | | | | 2 | Mesic Organic Cryosol |
| | | | | 3 | Humic Organic Cryosol |
| | | | | 4 | Terric Fibric Organic Cryosol |
| | | | | 5 | Terric Mesic Organic Cryosol |
| | | | | 6 | Terric Humic Organic Cryosol |
| | | | | 7 | Glacic Organic Cryosol |
| 4 | Gleysolic | 1 | Humic Gleysol | 1 | Orthic Humic Gleysol |
| | | | | 2 | Rego Humic Gleysol |
| | | | | 3 | Fera Humic Gleysol |
| | | 2 | Gleysol | 1 | Orthic Gleysol |
| | | | | 2 | Rego Gleysol |
| | | | | 3 | Fera Gleysol |
| | | 3 | Luvic Gleysol | 1 | Orthic Luvic Gleysol |
| | | | | 2 | Humic Luvic Gleysol |
| | | | | 3 | Fera Luvic Gleysol |
| | | | | 4 | Fragic Luvic Gleysol |
| 5 | Luvisolic | 1 | Gray Brown Luvisol | 1 | Orthic Gray Brown Luvisol |
| | | | | 2 | Brunisolic Gray Brown Luvisol |
| | | | | 3 | Podzolic Gray Brown Luvisol |
| | | | | 4 | Gleyed Gray Brown Luvisol |
| | | | | 5 | Gleyed Brunisolic Gray Brown Luvisol |
| | | | | 6 | Gleyed Podzolic Gray Brown Luvisol |

| CODE | ORDER | CODE | GREAT GROUP | CODE | SUBGROUP |
|---|---|---|---|---|---|
| | | 2 | Gray Luvisol | 1 | Orthic Gray Luvisol |
| | | | | 2 | Dark Gray Luvisol |
| | | | | 3 | Brunisolic Gray Luvisol |
| | | | | 4 | Podzolic Gray Luvisol |
| | | | | 5 | Solonetzic Gray Luvisol |
| | | | | 6 | Fragic Gray Luvisol |
| | | | | 7 | Gleyed Gray Luvisol |
| | | | | 8 | Gleyed Dark Gray Luvisol |
| | | | | 9 | Gleyed Brunisolic Luvisol |
| | | | | 10 | Gleyed Podzolic Gray Luvisol |
| | | | | 11 | Gleyed Solonetzic Gray Luvisol |
| | | | | 12 | Gleyed Fragic Gray Luvisol |
| 6 | Organic | 1 | Fibrisol | 1 | Typic Fibrisol |
| | | | | 2 | Mesic Fibrisol |
| | | | | 3 | Humic Fibrisol |
| | | | | 4 | Limno Fibrisol |
| | | | | 5 | Cumulo Fibrisol |
| | | | | 6 | Terric Fibrisol |
| | | | | 7 | Terric Mesic Fibrisol |
| | | | | 8 | Terric Humic Fibrisol |
| | | | | 9 | Hydric Fibrisol |
| | | 2 | Mesisol | 1 | Typic Mesisol |
| | | | | 2 | Fibric Mesisol |
| | | | | 3 | Humic Mesisol |
| | | | | 4 | Limno Mesisol |
| | | | | 5 | Cumulo Mesisol |
| | | | | 6 | Terric Mesisol |
| | | | | 7 | Terric Fibric Mesisol |
| | | | | 8 | Terric Humic Mesisol |
| | | | | 9 | Hydric Mesisol |
| | | 3 | Humisol | 1 | Typic Humisol |
| | | | | 2 | Fibric Humisol |
| | | | | 3 | Mesic Humisol |
| | | | | 4 | Limno Humisol |
| | | | | 5 | Cumulo Humisol |
| | | | | 6 | Terric Humisol |
| | | | | 7 | Terric Fibric Humisol |
| | | | | 8 | Terric Mesic Humisol |
| | | | | 9 | Hydric Humisol |
| | | 4 | Folisol | 1 | Typic Folisol |
| 7 | Podzolic | 1 | Humic Podzol | 1 | Orthic Humic Podzol |
| | | | | 2 | Ortstein Humic Podzol |
| | | | | 3 | Placic Humic Podzol |
| | | | | 4 | Duric Humic Podzol |
| | | | | 5 | Fragic Humic Podzol |

| CODE | ORDER | CODE | GREAT GROUP | CODE | SUBGROUP |
|---|---|---|---|---|---|
| | | 2 | Ferro-Humic Podzol | 1 | Orthic Ferro-Humic Podzol |
| | | | | 2 | Ortstein Ferro-Humic Podzol |
| | | | | 3 | Placic Ferro-Humic Podzol |
| | | | | 4 | Duric Ferro-Humic Podzol |
| | | | | 5 | Fragic Ferro-Humic Podzol |
| | | | | 6 | Luvisolic Ferro-Humic Podzol |
| | | | | 7 | Sombric Ferro-Humic Podzol |
| | | | | 8 | Gleyed Ferro-Humic Podzol |
| | | | | 9 | Gleyed Ortstein Ferro-Humic Podzol |
| | | | | 10 | Gleyed Sombric Ferro-Humic Podzol |
| | | 3 | Humo-Ferric Podzol | 1 | Orthic Humo-Ferric Podzol |
| | | | | 2 | Ortstein Humo-Ferric Podzol |
| | | | | 3 | Placic Humo-Ferric Podzol |
| | | | | 4 | Duric Humo-Ferric Podzol |
| | | | | 5 | Fragic Humo-Ferric Podzol |
| | | | | 6 | Luvisolic Humo-Ferric Podzol |
| | | | | 7 | Sombric Humo-Ferric Podzol |
| | | | | 8 | Gleyed Humo-Ferric Podzol |
| | | | | 9 | Gleyed Ortstein Humo-Ferric Podzol |
| | | | | 10 | Gleyed Sombric Humo-Ferric Podzol |
| 8 | Regosolic | 1 | Regosol | 1 | Orthic Regosol |
| | | | | 2 | Cumulic Regosol |
| | | | | 3 | Gleyed Regosol |
| | | | | 4 | Gleyed Cumulic Regosol |
| | | 2 | Humic Regosol | 1 | Orthic Humic Regosol |
| | | | | 2 | Cumulic Humic Regosol |
| | | | | 3 | Gleyed Humic Regosol |
| | | | | 4 | Gleyed Cumulic Humic Regosol |
| 9 | Solonetzic | 1 | Solonetz | 1 | Brown Solonetz |
| | | | | 2 | Dark Brown Solonetz |
| | | | | 3 | Black Solonetz |
| | | | | 4 | Alkaline Solonetz |
| | | | | 5 | Gleyed Brown Solonetz |
| | | | | 6 | Gleyed Dark Brown Solonetz |
| | | | | 7 | Gleyed Black Solonetz |
| | | 2 | Solodized Solonetz | 1 | Dark Solodized Solonetz |
| | | | | 2 | Dark Brown Solodized Solonetz |
| | | | | 3 | Black Solodized Solonetz |
| | | | | 4 | Dark Gray Solodized Solonetz |
| | | | | 5 | Dark Solodized Solonetz |
| | | | | 6 | Gleyed Brown Solodized Solonetz |
| | | | | 7 | Gleyed Dark Brown Solodized Solonetz |
| | | | | 8 | Gleyed Black Solodized Solonetz |
| | | | | 9 | Gleyed Dark Gray Solodized Solonetz |
| | | | | 10 | Gleyed Gray Solodized Solonetz |

| CODE | ORDER | CODE | GREAT GROUP | CODE | SUBGROUP |
|---|---|---|---|---|---|
| | | 3 | Solod | 1 | Brown Solod |
| | | | | 2 | Dark Brown Solod |
| | | | | 3 | Black Solod |
| | | | | 4 | Dark Gray Solod |
| | | | | 5 | Gray Solod |
| | | | | 6 | Gleyed Brown Solod |
| | | | | 7 | Gleyed Dark Brown Solod |
| | | | | 8 | Gleyed Black Solod |
| | | | | 9 | Gleyed Dark Gray Solod |
| | | | | 10 | Gleyed Gray Solod |

## APPENDIX D

## CODES ASSIGNED TO SOIL TEXTURAL CLASSES

| CODE | TEXTURE |
|---|---|
| 1 | Sand |
| 2 | Loamy sand |
| 3 | Sandy loam |
| 4 | Loam |
| 5 | Silty loam |
| 6 | Silt |
| 7 | Silty clay loam |
| 8 | Clay loam |
| 9 | Sandy clay loam |
| 10 | Sandy clay |
| 11 | Silty clay |
| 12 | Clay |
| 13 | Heavy clay |